Passive Microwave Radiation Effects on the TOPEX Altimeter Cal-2 Measurements

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Overview

The TOPEX radar altimeter's Calibration Mode 2 measurements of receiver noise have exhibited more variation, calibration-to-calibration, during the flight (on-orbit) mission than was evident during the ground testing. The calibration mode assesses adequately the launch-to-date calibration trends, but the signal variations about these trends have remained a matter of curiosity. We have concluded that during this calibration submode the receiver is sensitive to passive microwave radiation from the Earth's surface. The level of received radiation is observed to vary, depending on the type of terrain at nadir during each calibration.

Internal Calibration Mode

The altimeter's internal calibration mode has two submodes, Cal-1 and Cal-2. Cal-1 detects internal path delay changes for the monitoring of range drift, and also monitors received signal level for internal changes of the transmitter and receiver. The second submode, Cal-2, characterizes the response of the receiver and digital filter bank to signal noise.

In Cal-1, a portion of the transmitter output is fed to the receiver through a digitally controlled calibration attenuator. Cal-1 range and received signal implications are discussed by Hayne *et al* (1994) and by Callahan *et al* (1994) in Issue 3 of TOPEX / POSEIDON Research News.

In Cal-2, the altimeter processes receiver thermal noise, with no transmitted signal present, to characterize the receiver and waveform sampler response. The waveguide port is open to the antenna.

When commanded to calibration mode, the TOPEX altimeter first enters Cal-1 and then automatically switches to Cal-2. The calibration mode lasts approximately four minutes, about three minutes in Cal-1 and then one minute in Cal-2. Early in the mission there were four altimeter calibrations per day, but after the first few months there have been two per day. The calibration mode is normally scheduled over-land to avoid loss of over-ocean data, but some over-ocean calibrations have occurred such as when a transition is made between the TOPEX

altimeter and the SSALT altimeter.

Launch-to-Date Cal-2 Results

Since initial on-orbit turn-on of the TOPEX altimeter, there have been over 1600 calibrations; their geographic distribution is shown in Figure 1. The gray-scale of Figure 1 is indicative of the relative Ku-Band Cal-2 measured power, in dB, where the lower-value calibrations are depicted in darker tones and the higher values in lighter tones. The relative value of the Cal-2 appears to be geographically correlated.

The TOPEX launch-to-date Cal-2 measurements relative to fixed reference points, in ΔdB, are shown in Figures 2 and 3 for Ku-Band and C-Band, respectively. Reference Cal-2 powers, for Ku-Band and for C-Band, were established early in the mission, and the deltas represent the measurements minus the reference. Ku-Band Cal-2 measurements are observed to have a generally linear trend with respect to time, decreasing about 0.3 dB since launch, probably due to aging of system components. A linear fit to the Ku-Band deltas, excluding the large negative excursions, indicates a measurement change rate of approximately 0.12 dB per year. The C-Band Cal-2 measurements do not exhibit any long-term trends.

Data spikes are very noticeable in both the Ku- and C-Band data sets. These spikes appear simultaneously in both frequencies and are predominantly negative, but some positive ones are noted.

During the pre-launch testing of the altimeter, the Cal-2 results were quite consistent, with no data spikes such as are evident in

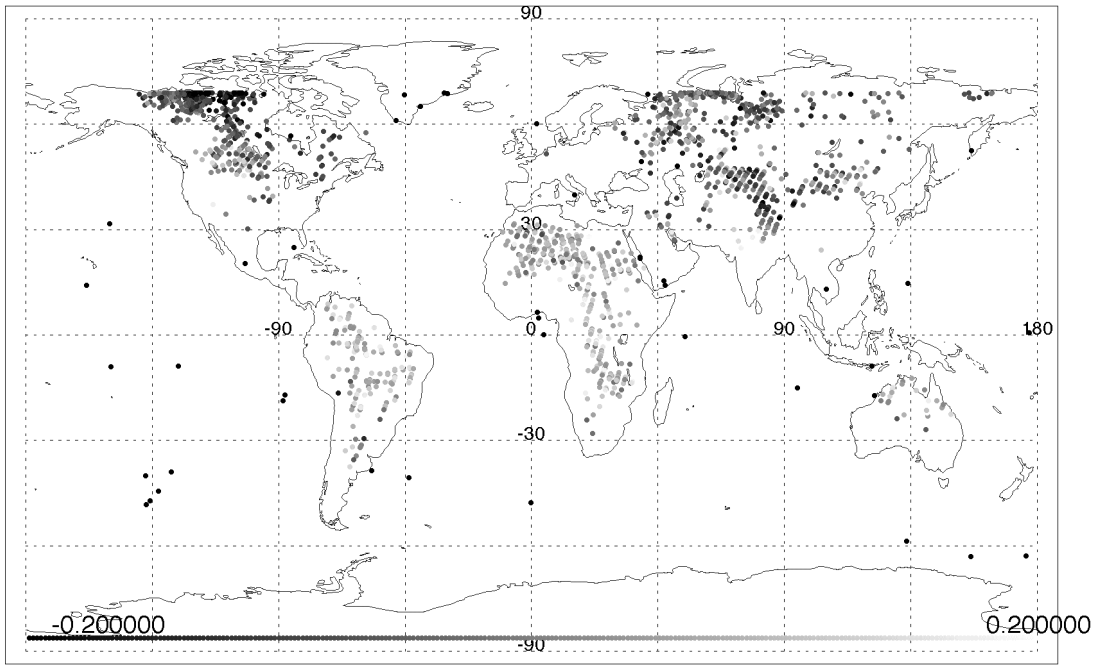

Figure 1 : Geographic distribution of Cal-2 measurements from Launch to Cycle 92. Darker gray-scale tones indicate lower measurement values. The gray-scale bar, from -0.2 dB to +0.2 dB, is at the bottom of the figure.

the on-orbit data in Figures 2 and 3. We have been studying the occurrences of these spikes, to interpret them and to assure ourselves that the altimeter itself continues to perform well.

Effects of Differing Terrain/Vegetation on Cal-2 Measurements

Our analysis of the TOPEX Cal-2 measurements reveals that the data spikes can be attributed to the varying types of terrain or vegetative cover at nadir at the time of the calibration. While we expected a Cal-2

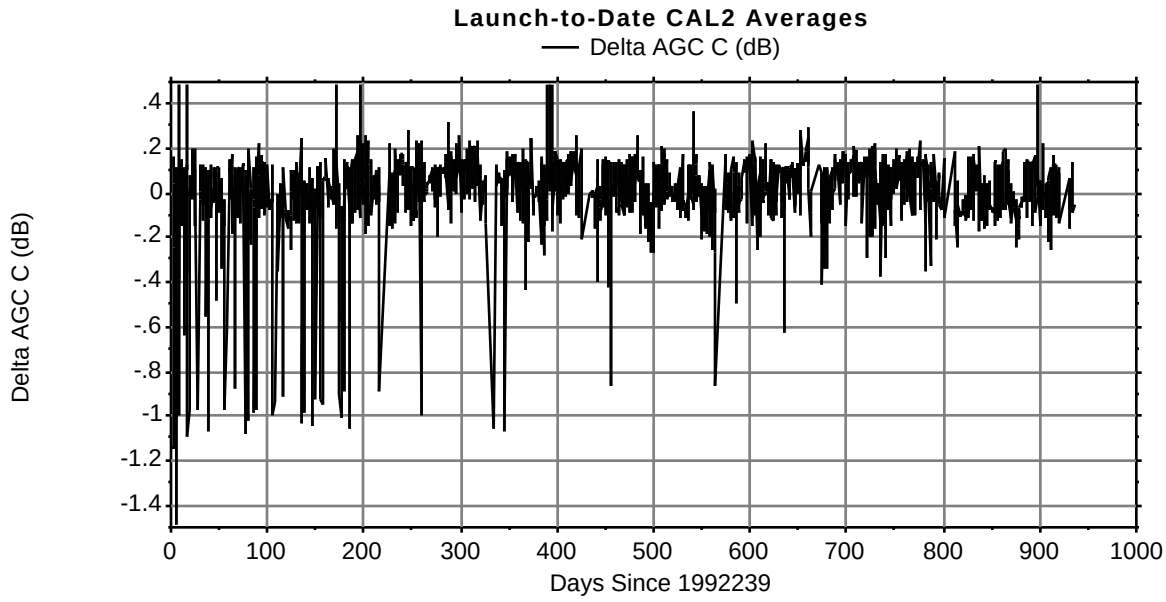

Figure 3 : Launch-to-Date Cal-2 C-Band Delta AGC .
Each point is the average for the 60-second Cal-2 data span.

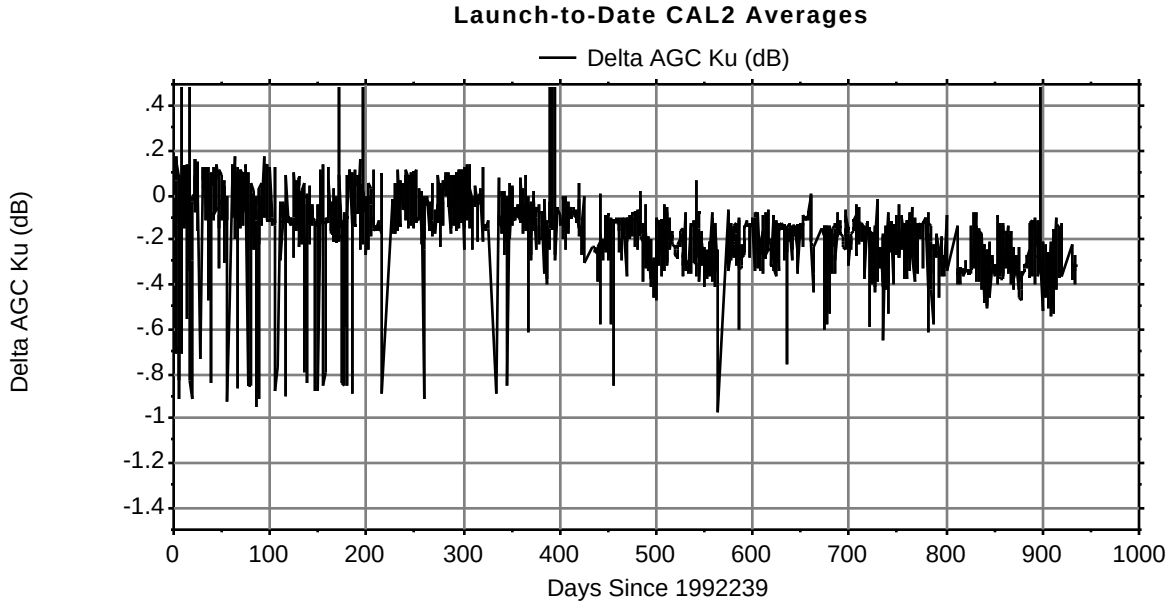

Figure 2 : Launch-to-Date Cal-2 Ku-Band Delta AGC.
Each point is the average for the 60-second Cal-2 data span.

system performance measurement based on noise only, there are obviously background signals due to passive microwave radiation from the Earth's surface.

For example, the large negative (approximately -0.9 dB) delta spikes in Figures 2 and 3, which occurred frequently during the early part of the mission and occasionally since then, correspond with over-ocean calibrations during altimeter transitions (TOPEX-to-SSALT or SSALT-to-TOPEX) or during special tests. The altimeter switchovers and special tests occurred much more often during the early part of the mission.

The smaller, over-land, measurement spikes are attributed to variations in the terrain or the terrain vegetative cover. We have selected discrete geographic areas of Ku-Band Cal-2 measurements within which the terrain and vegetation type are generally uniform. The results of our study are summarized in Table 1, where the delta Cal-2 measurements are shown to be sensitive to the terrain-type and the season. The values shown in Table 1 are relative to the long-term linear fit.

During Cal-2, the altimeter is in effect a radiometer. In this mode, the system temperature is estimated to be 438.4° K and the blackbody room temperature is 290° K (Paul Marth, JHU / APL, private communication). Using an emissivity of 0.5 for water and 1.0 for land yields water temperatures of 538.3° K and 728.4° K for land, which implies that the nominal radiation difference between land and water is 0.9 dB. This is very close to the observed power difference in Table 1 between grasslands and open ocean of 0.92 dB.

There were very few instances when a calibration occurred over sea ice or the Greenland ice sheet, but the results for ice are very similar, about -0.55 dB. The relative Cal-2 values for frozen tundra and snow-covered mountains are also negative.

The highest relative Cal-2 values (+0.13 dB) observed in this study are associated with the Amazon rain forest in the summer.

Study Area	Type of Terrain	Number of Samples	Cal-2 Average (dB)
Various	Open Ocean	13	-.082 ± 0.10
58° - 66.2° N 308° - 335°E	Sea Ice	2	-0.57 ± 0.03
65° - 66.2° N 310° - 320° E	Greenland Ice Sheet	1	-0.52
65° - 66.2° N	Tundra (Frozen)	6	-0.17 ± 0.07
225° - 265° E	Tundra (Spring)	1	-0.06
12° - 20°S 305° - 310°E	Grasslands	9	+0.10 ± 0.06
0° - 8° S	Rain Forest (Fall-Spring)	15	+0.05 ± 0.09
292° - 298° E	Rain Forest (Summer)	9	+0.13 ± 0.05
20° - 30° N	Sahara Desert (Spring-Summer)	25	+0.10 ± 0.12
10° - 20° E	Sahara Desert (Fall-Winter)	25	+0.06 ± 0.12
65° - 66.2° N	Mountains (January)	4	-0.10 ± 0.04
223° - 227° E	Mountains (May)	3	+0.01 ± 0.03

Table 1: Table of Delta Ku Cal-2 Measurements

Smaller positive values occur over the grasslands (savannah) of South America, and over the Sahara Desert.

The TOPEX altimeter has a 0.25 dB resolution for power measurements. This design was based on the ocean being a noisy surface and then allowing the data averaging to provide mean power values. Normally the Cal-2 noise is below this resolution and during a single Cal-2, each measurement may be exactly the same or may toggle the 0.25 dB resolution step. Figure 4 shows data from individual Cal-2s with one-second averaging. Some of these display a stepping that comes from the 0.25 dB resolution, but it is clear that within a single Cal-2 the data are quite steady unless a terrain-type transition occurs during the calibration.

The effect of a transition in terrain during a Cal-2 is clearly depicted in Figure 5 where the at-nadir terrain in northern Canada starts off as mountains, briefly changes to a tundra / water mixture within the altimeter footprint as the groundtrack skims the edge of a lake, changes back to all land, then to a tundra / water mixture again, and finally changes to all water over Great Bear Lake (66˚N latitude). Because this calibration occurred on day 233 of 1994, the surface of Great Bear Lake is expected to be ice-free, and the Cal-2 level of -0.72 dB indicates that this is indeed the case. A Cal-2 which passed over the Great Bear Lake on day 53 of 1994 yielded a delta Cal-2 of -0.49dB, indicative of an ice-covered surface at that time.

Conclusion

During Cal-2, the TOPEX altimeter receives background passive microwave radiation from the Earth's surface, and the amount of radiation is dependent on the nature of the terrain at nadir. As a result of this study, we have an improved understanding of why the delta Cal-2 measurements since launch have been so variable calibration-to-calibration. Fortunately, the long-term Cal-2 trends have remained discernible throughout the

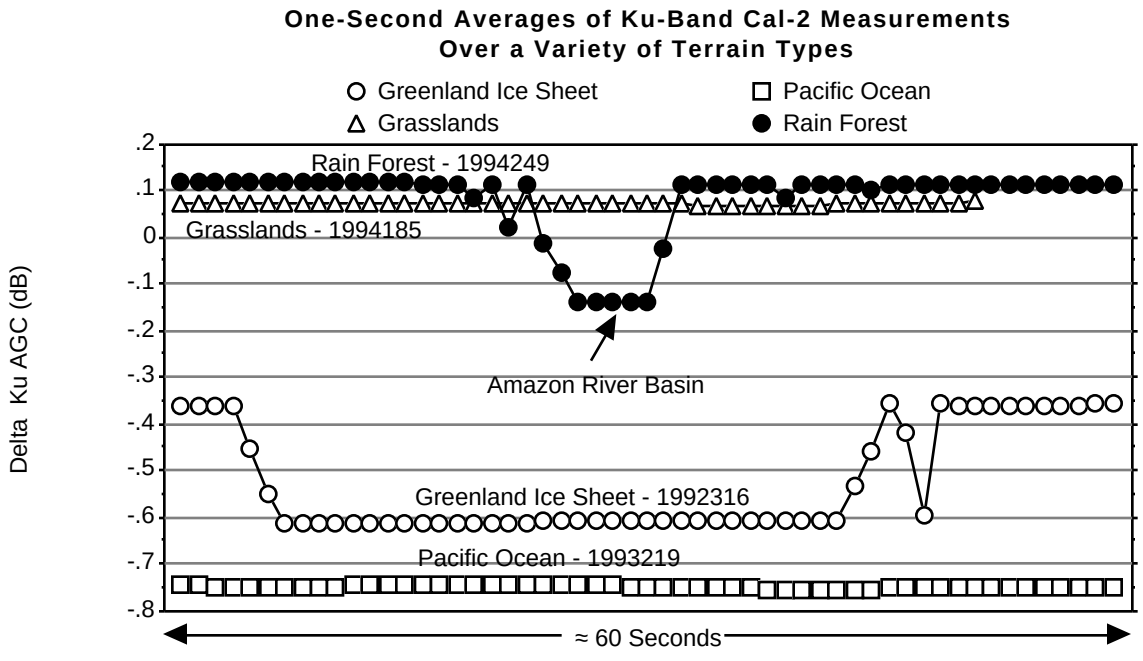

Figure 4 : Ku-Band Cal-2 measurements for a variety of terrain types. Data rate for each is one-per-second and data span is approximately 60 seconds.

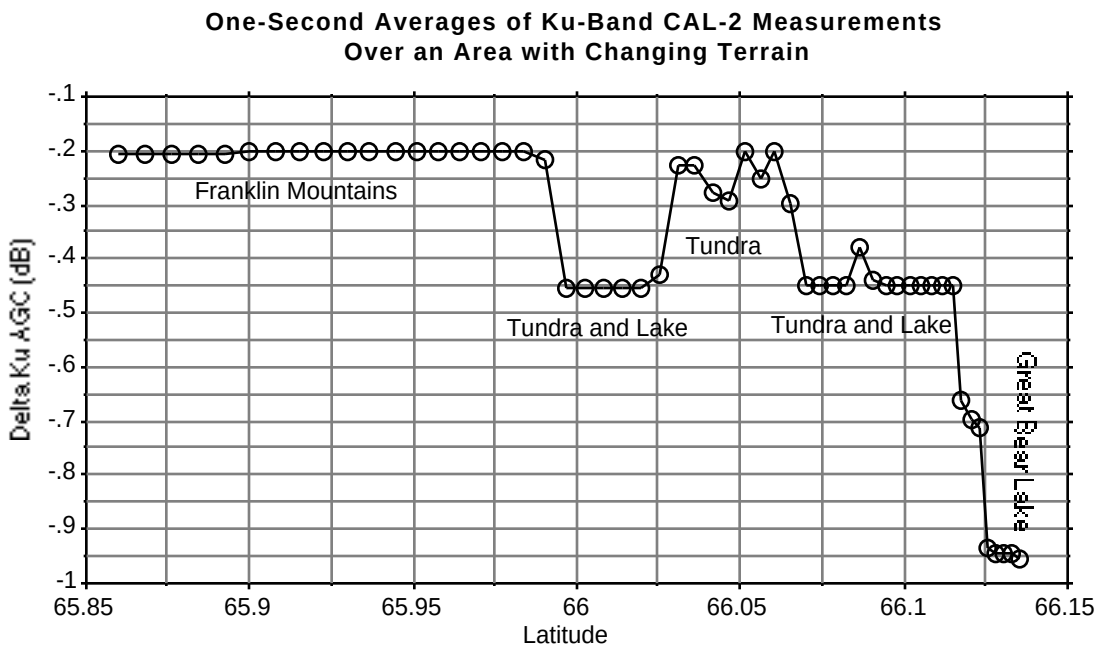

Figure 5: Ku-Band Cal-2 measurements over an area with changing terrain, on day 233 of 1994. Data rate is one-per-second and data span is approximately 60 seconds.

mission.

This insight into the Cal-2 process will help us interpret future TOPEX altimeter Cal-2 measurements, and will assist in the understanding of similar measurements on future altimeter missions.

Acknowledgments

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References

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